DESIGN INSTALLATION OPERATION & MAINTENANCE COMMISSIONING

Sizing Single-Package Rooftop Units for Optimum Performance

A whole-building approach to selecting the right unit

By PETER C. JACOBS,
Architectural Energy Corp.,
Boulder, Colo., and
MARK A WILLIAMS,
The New Buildings Institute
White Salmon, Wa.

Editor's note: The New Buildings Institute (NBI) is conducting a Public Interest Energy Research (PIER) project for the California Energy Commission (CEC). NBI's project is called Integrated Energy Systems - Productivity and Buildings Science Program. As the name suggests, it is not individual building components, equipment, or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction, and operation of building systems. The overall project has several elements, covering HVAC, thermal distribution, daylighting/skylighting, ceiling systems, and exterior-lighting systems. The focus of this article is on small HVAC systems for commercial buildings.

Direct expansion (DX) air conditioners and heat pumps cool more than half of the total commercial new construction floor space in California. Of these, single-package rooftop air conditioners dominate the market, representing approximately three-quarters of the total DX system capacity. The rooftop air-conditioner market is dominated by small systems, defined here as systems 10 tons and smaller, representing almost 60 percent of the total installed DX cooling capacity. The most popular unit size (in terms of units sold) is 5 tons; the second most popular unit size is 10 tons (figures 1–3).

These small rooftop units are the "workhorses" of the commercial-buildings industry, yet many systems fail to reach their full potential due to problems with design, installation, and operation. The focus of this article is on building design, sizing, and specification issues; future articles will address installation, operations and maintenance, and commissioning.

DESIGN ISSUES

Roofing materials. Roofing materials with low solar absorptance and high thermal emittance ("cool" roofs) can reduce peak HVAC loads and energy consumption. Cool roofs work to reflect solar radiation while enhancing radiant heat transfer to the sky, thus reducing the "roof" load of the building. Reductions in heat gains though the roof impact the temperature of the plenum space located between the drop ceiling and the roof, which contains the majority of the ductwork in small commercial buildings. Duct heat gains and air-leakage losses (especially on the return side) can increase HVAC loads on the order of 30 percent, so a cool plenum can reduce energy con-

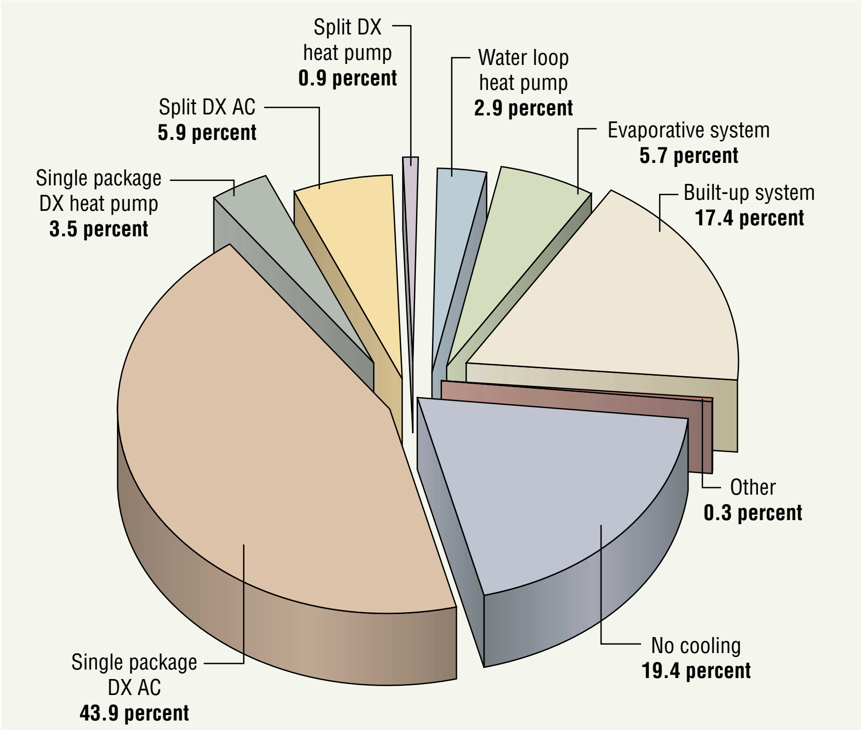

FIGURE 1. Floor space distribution of HVAC systems in new commercial buildings in California. Note that single-package DX air conditioners are the most popular HVAC-system type in new construction in the state, cooling about 44 percent of the total floor space.

Peter C. Jacobs, PE, is a senior engineer at Architectural Energy Corp.in Boulder Colo. He has been involved in energy efficiency and renewable energy issues for over 20 years. He can be reached at pjacobs@archenergy.com. *Mark A. Williams, CEM,is a registered architect with 22 years of experience in energy efficient commercial building design, analysis, and operation. He can be reached at* mwilliams@newbuildings.org.

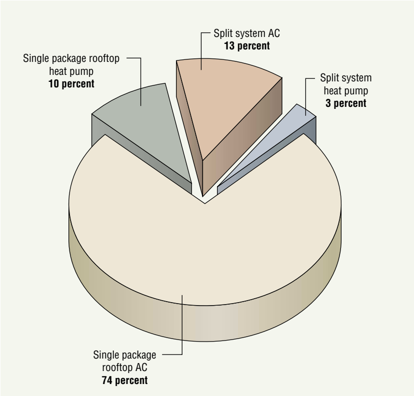

FIGURE 2. Distribution of DX system types by installed capacity. Single package equipment is the most popular packaged DX system type in new commercial buildings. Split systems and heat pumps, although present, do not represent a large fraction of the number of systems or installed cooling capacity.

sumption and improve occupant comfort, especially in commercial buildings where systems run continuously during occupied hours. Cool roofs can also reduce the outdoor air temperature at the roof level.

Insulation location. The roof or ceiling insulation location can also have a major effect on HVAC system performance. Roof insulation can be installed directly on the roof deck, while ceiling insulation is generally applied on top of the drop ceiling ("lay-in" insulation). When the insulation is applied to the roof, the plenum is located within the thermal envelope of the building, and the impacts of duct conductive losses and duct leakage on HVAC system efficiency are substantially less. Lay-in insulation generally has incomplete coverage, because common recessed lighting fixtures cannot be insulated, and the insulation is often disturbed after construction for a variety of reasons (Photo A).

Sizing issues. Many small HVAC systems are significantly oversized, resulting in inefficient operation, reduced reliability due to frequent cycling of compressors, and poor humidity control. Oversized systems also result in wasted capital investment in both the HVAC unit and the distribution system. Oversizing also affects the ability of the system to provide simultaneous economizer and compressor operation, and exacerbates problems with distribution-system fan power because larger units are supplied with larger fans. The resulting larger duct systems also present more surface area for heat transfer and greater air leakage potential.

A variety of sizing methodologies are used to determine HVAC system size, including "rule of thumb" sizing based on square foot per ton, manual methods (e.g., ACCA Manual N), and computerized load calculations. Although computerized methods are used most frequently, the assumptions used to develop input data can lead to oversizing. Engineers often base HVAC-sizing decisions on the full nameplate or "connected" load of computers, copiers, printers, and so on, and assume simultaneous operation of such equipment. In fact, most of this equipment operates at a fraction of the nameplate value and rarely operates simultaneously.

The peak occupant load and the corresponding ventilation load can contribute substantially to equipment capacity in certain spaces, such as lobbies and public assembly areas. Often, actual occupant loads are substantially less than peak egress loads that the building codes defer to. While code changes may be in order, it also makes sense for designers to know the applicable code well and balance good air quality with energy efficiency. Many building codes reference ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*, which allows the designer to base the design on a realistic occupant density, so long as justification is provided. Demand-controlled ventilation (DCV) is becoming popular and is offered by several manufacturers as a factory-installed option in packaged equipment. This provides ventilation tailored to actual occupant loads at any point in time.

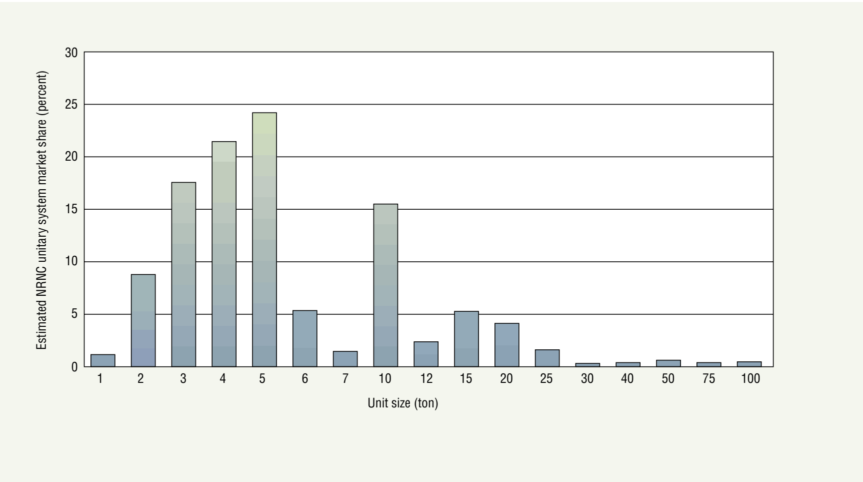

FIGURE 3. Distribution of packaged DX system size. In terms of number of systems installed, the most popular packaged DX system size is 5 tons. Units between 1 and 10 tons represent close to 90 percent of the total unit sales in new buildings in California.

SELECTION ISSUES

Unit efficiency. Energy codes are generally set to correspond to the basic "standard-efficiency" HVAC unit. High-efficiency units are available in most size ranges that are 10-20 percent more efficient than code. These units generally incorporate larger heat exchangers, efficient compressors, improved cabinet insulation, and higher-efficiency fans and motors. Design should focus more on the rated full load energy efficiency ratio (EER), because the seasonal energy efficiency ratio (SEER) may not be a good indication of unit efficiency during peak cooling loads.

Fan power. Efficient fans are important in commercial applications because they generally run continuously during occupied periods. In systems equipped with economizers in mild climates such as coastal California, fan energy can be a significant portion of the total HVAC energy consumption. The static-pressure assumptions used to generate system-efficiency ratings are lower than those encountered in the field. Fan power during normal operation can be 50 percent

PHOTO A. Lay-in insulation applied to a warehouse-to-office conversion project. Note the poor insulation coverage and ductwork located in an unconditioned space.

greater than rated values. Limiting the use of flex ductwork can substantially reduce static pressure and fan power.

Economizers. Economizers are required by code in some units and used in many smaller units. Our research shows failure rates approaching 70 percent. Although most manufacturers offer a factory installed economizer, the majority of economizers are installed by the distributor or in the field. Specifying a factory installed and fully run-tested economizer can improve reliability

Thermostats. The primary function of the thermostat is to control the heating and cooling output of the unit, but most thermostats also control the operation of the supply fan. Fans are required to run continuously during operating hours, and cycle on and off with a call for heating or cooling during unoccupied hours. Most of the systems we studied have the capability to implement this strategy, yet were not set up correctly, with potentially severe implications for indoor air quality (Figure 4). Designers should specify controls with "default" settings that are appropriate for commercial applications and that are user friendly.

SUMMARY

While specifying high-efficiency HVAC equipment is important, a host of other design and specification issues, such as roof color, insulation location, sizing assumptions, thermostat type, and economizer supplier can influence the energy efficiency and comfort of buildings with small HVAC systems. Next month, we will address several installation issues that can help to improve the efficiency of small HVAC systems in commercial buildings.

BIBLIOGRAPHY

See the results of the market research conducted for this project, as well as other program research reports, at *www.newbuildings.org/pier.*

"State of the Art Review, Whole Building, Building Envelope, and HVAC Component and System Simulation and Design Tools", American Refrigeration Technology Institute, Arlington, VA. *www.arti-21cr.org.*

Komor, P., December, 1997. "Space cooling demands from office plug loads," *ASHRAE Journal*, vol.39, no.12, 41-44.

For previous Equipment Notebook articles, visit www.hpac.com.

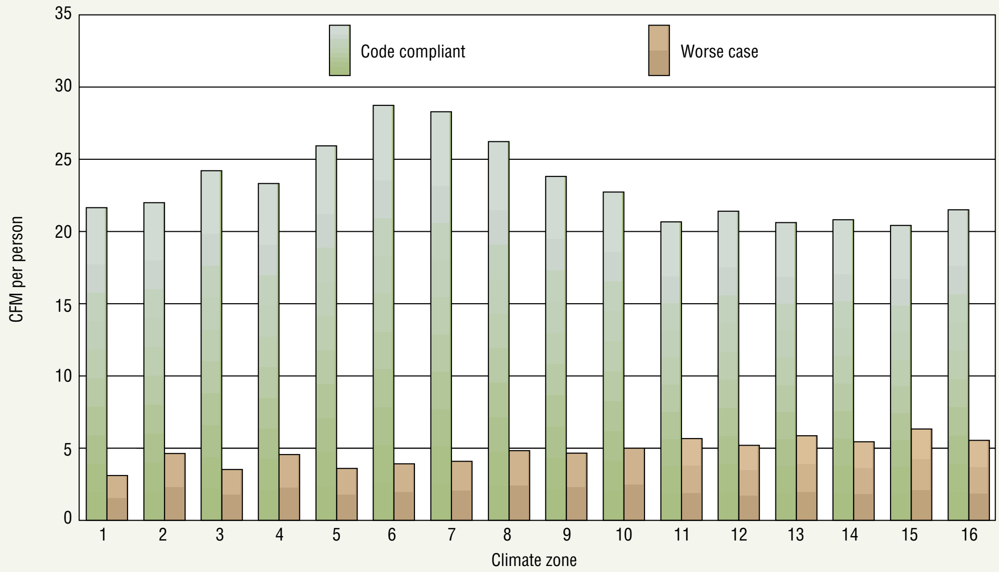

FIGURE 4. Effective ventilation rate for HVAC units with continuous and cycling fans. In both cases, the minimum outdoor air damper is set to provide 15 cfm/person of outside air. The code-compliant case used continuous ventilation and an air-side economizer. Economizer operation increased the effective ventilation rate above the nominal 15 cfm/person rate. A unit not equipped with an economizer and operated with cycling fans provided an effective ventilation rate of less than 5 cfm/person in most climate zones.